Moulton Spalding and by another observer at Oxford in 1880, April 7, at $8^h\ 17^m$ ('Observatory,' iii. pp. 414 and 536). This belonged to a radiant at 38° +18° and its origin is doubtless to be referred to the same stream as that of the small bolide of April 4 previously described. The apparent centre of divergence of this pair of doubly observed meteors was at about 34° +18°, but the zenithal attraction would require a correction of several degrees to the observed place, so that the radiant would be really about 30° +11°. Meteors from positions below the horizon are somewhat rare, though I have occasionally seen them. In 1879, Nov. 12, $10^h\ 17^m$, I noticed a bright Leonid with a path of 98°, though the radiant had not then risen. This meteor was also seen by Mr. Corder at Chelmsford, and Mr. Grey at Bedford. On Oct. 20 of the same year, at $8^h\ 32^m$ I registered a 1st mag. Orionid moving slowly from 86½° +22° to 79° +29½° and leaving a remarkably bright streak. The radiant was slightly below the horizon.

In the recently published 'Beobachtungen Angestellt am astrophysikalischen Observatorium in O'Gyalla' (Ungarn, 1885), by Dr. Nicolaus v. Konkoly, are given the paths of 647 meteors observed in that year, together with a list of 71 radiant-points deduced by Dr. v. Kövesligethy. These radiants include many positions for the Perseids, Cassiopeids, and other well-known displays of the August epoch. The best average positions derived from Dr. Kövesligethy's list are :—

Average radiant.	No. of Meteors.	Positions averaged.	Epoch 1885.	Notes.
° °				
5 +65	29	3	August 8–12	These showers in the region of Cassiopeia and Andromeda are unquestionably distinct, reappearing every year with the Perseids.
13 +52	47	6	August 8–12	
24 +59	12	3	July 27, Aug. 9	
25 +44	12	2	August 3–9	
30 +28	13	2	August 10–12	Shower in Triangulum.
47 +58	104	17	August 6–12	Perseids. Max. Aug. 10.
69 +51	13	2	August 10–12	Weiss, 70° +53°, Aug. 13, 1869.
154 +61½	15	3	August 10–12	Shower near α–β Ursæ Maj.
312 +47	16	3	August 3–9	Greg's Cygnids I. at 309° +48°.

Dr. Konkoly's volume also contains the positions of 15 stationary meteors.

W. F. Denning.

The Applications of Photography in Astronomy.*

Little more than a year ago Mr. Ainslie Common delivered a lecture in this place on the subject of "Photography as an aid to Astronomy." Given by one who is a consummate master of the

* Lecture delivered by David Gill, LL.D., F.R.S., Her Majesty's Astronomer at the Cape of Good Hope, on Friday, June 3, 1887, before the Royal Institution of Great Britain. By kind permission of the Lecturer.

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art of celestial photography, that lecture (complete as to history and full of suggestion as it was) would, under ordinary circumstances, have precluded further reference to the subject in these Friday evening lectures for some years to come.

But the past year has witnessed such developments of the subject, and the importance of photography in astronomy has been so much advanced by the conclusions of the recent Astro-photographic Congress, as to afford a reasonable apology for the present lecture.

On the 16th of April last there was held at Paris a Congress attended by upwards of fifty astronomers and physicists, representing nearly every civilized nation in the world. It was convened for the purpose of considering a scheme of international co-operation in the work of charting the sky on a large scale. Or, rather, its object was to obtain a series of pictures, which, taken within a comparatively limited period of time, and with the necessary precautions, would enable astronomers of the present day to hand down to future generations a complete record of the positions and magnitudes of all the stars in the heavens to a given order of magnitude. The labours of that Conference are now concluded, certain important resolutions have been adopted, and the way has been so far cleared for giving these resolutions practical effect.

It seems of importance therefore to lay before the members of the Royal Institution some account of the history of this remarkable Congress, to illustrate and explain the grounds of the conclusions which it has arrived at, and otherwise to bring the history of photographic astronomy up to the present date. I pass over the already well-told early history of celestial photography, except in so far as it relates to star-charting. It was Warren de la Rue who first called attention to the means furnished by photography for charting groups of stars. In his Report to the British Association at Manchester in 1861 on the progress of celestial photography, he indicates a photographic object-glass of short focus as the instrument best suited for the purpose, and he states that by mounting such a lens and camera on an equatoreal stand provided with clockwork he has photographed such groups of stars as the Pleiades, the chief difficulty being not to fix the images of the stars, but to distinguish them from the specks which are found on the plates or rather in the collodion.

In 1864, Rutherfurd of New York completed a telescope of $11\frac{1}{2}$ inches aperture and 14 feet focal length, specially constructed for celestial photography, and obtained fine photographs of stars to the 9th order of magnitude. His remarks, although quoted in Mr. Common's lecture last year, have such importance on the present subject that I venture to repeat them.

"The power to obtain images of the 9th magnitude stars with so moderate an aperture promises to develop and increase the application of photography to the mapping of the sidereal heavens and in some manner to realize the hopes which have so long been deferred and disappointed.

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"It would not be difficult to arrange a camera-box, capable of exposing a surface sufficient to obtain a map of two degrees square, and with instruments of large aperture we may hope to reach much smaller stars than I have yet taken. There is also every probability that the chemistry of photography will be very much improved and more sensitive methods devised."

Mr. Common well remarks that in the light of recent work these words are almost prophetic.

But Rutherfurd did not stop here. In the eye of an astronomer a picture of stars is of comparatively little importance unless it is capable of accurate measurement. Recognizing this important feature of the case, Rutherfurd devised a suitable apparatus, which he applied to the measurement of two of his photographs of the Pleiades. These measures having been put into the hands of Dr. Gould, that astronomer compared them with those of the same group of stars made by Bessel with his celebrated heliometer, and found a satisfactory accordance *.

Encouraged by these results, Dr. Gould, when he went to the Argentine Republic in 1870 to found the Cordoba Observatory, which has since been rendered so famous by his labours, took Rutherfurd's telescope with him. Unfortunately one of the lenses was broken in transport, and such delay was incurred in replacing it, that the proposed work could not be begun till 1875. But thanks to the clear skies of Cordoba, and the marvellous activity of the observatory under Dr. Gould's direction, 1350 photographs were obtained in the course of a few years, containing representations of all the principal star-clusters of the southern hemisphere, besides a special series of plates taken for the purpose of determining the parallax (or distance) of several of the more remarkable stars in the southern hemisphere.

This fine series of pictures is now being submitted to measurement by Dr. Gould, and the results are awaited with the greatest interest by all astronomers.

The first of Dr. Gould's plates were taken with the old wet collodion process, but the work was afterwards greatly facilitated by employment of the more sensitive modern dry plates.

It was, in fact, the introduction of the gelatine dry-plate process in 1876 which really paved the way for the rapid development of celestial photography. The convenience of the manipulation and the greater increase of sensitiveness of the plates at once placed a new power in the hands of astronomers. Draper photographed the nebula of Orion in 1880; and after trials, commencing in 1879, Common succeeded in obtaining the exquisite photographs of that object which have been exhibited more than once in this theatre.

In 1882 appeared the splendid comet of that year. At the Royal Observatory, Cape of Good Hope, we were not at the time engaged in photographic operations. Several photographers in

* Astron. Nach. No. 162, vol. xlviii. Dec. 1866.

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the Cape Colony found it possible to obtain impressions of the comet, but they were unable to secure pictures of scientific value, because they were unprovided with means to follow the diurnal motion. I had no available camera belonging to the observatory, and no experience in the development of modern dry plates. In these circumstances I applied to Mr. Allis, a skilful photographer in my neighbourhood, who eagerly consented to co-operate with me in the work. I arranged means to attach his camera to the stand of an equatoreal telescope, and the telescope itself was employed to follow the nucleus of the comet accurately during the whole time of exposure by the aid of the driving-clock and with small corrections given by hand. The lens employed had an aperture of only 2 inches, and a focal length of 11 inches; but the result was a series of pictures, one of which, obtained after an exposure of two hours, is now on the screen.

The photograph shows a very satisfactory delineation of the tail and envelope of the comet.

Important and useful as these results were, there was another feature of the pictures which seemed to me still more so. In forwarding copies of these photographs to the Royal Astronomical Society of London and to the Paris Academy of Sciences, I drew particular attention to the large number of stars shown upon the plate, and insisted upon the importance of the means thus offered to photograph comparatively large areas of the sky and thus rapidly make charts of the entire heavens.

The one step wanting was now provided, and the new and more sensitive dry plate rendered the former suggestions of De la Rue and Rutherfurd now valuable and practicable.

Formerly the old collodion wet plates required large instruments (with small field) and long exposure to depict stars even to the 9th magnitude, and astronomers trusted entirely to the accuracy of their driving-clocks, which could not follow a star with perfect accuracy during a long exposure. Now the modern rapid dry plates in conjunction with the large fields of the photographic objective overcame the first of these difficulties, and the plan of employing a guiding telescope overcame the second.

The use of a guiding telescope was not even a new device, for it had been employed long before by Hartnup and others, who, in their early attempts to photograph the Moon, kept the image of a lunar spot by hand upon the cross wires of the finder of the telescope during the long exposures then necessary.

There was thus nothing really new either in my suggestion or in the *modus operandi*, only the result was a fortunate one, for Mr. Common says that "these photographs came to him as a revelation of the power of photography for the purpose of star-charting"*, and Admiral Mouchez tells me that these Cape photo-

* 'Proc. Royal Institution,' vol. xii. part iii. p. 734.

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graphs and my suggestions first directed his attention and that of the brothers Henry to the application of photography to the work of star-charting, which had for many years been carried on at Paris by the older methods of astronomy.

Common was amongst the first to take up the work in England, and here on the screen is one of his photographs with a 4-inch lens executed in 1883. But being engaged in other researches, Common made no attempt to commence a systematic survey of the heavens.

Mr. Isaac Roberts, of Liverpool, was also early at work in the same field, and after preliminary experiments he acquired a powerful telescope, with which he began a systematic survey of the northern heavens.

It required some time to find the necessary means and apparatus to begin the realization of my ideas at the Cape, but at last the work was started in the beginning of 1885 on the following definite plan, viz. to complete the cartography of the heavens from 20° south of the Equator to the South Pole, and so as certainly to include all stars to the 9th magnitude.

The reasons for the adoption of this plan were the following:—

The celebrated astronomer Argelander charted the heavens on this scale from the North Pole to the Equator, and the work has recently been extended to 20° south of the Equator by Schönfeld, the pupil and successor of Argelander.

Argelander's 'Durchmusterung,' as it is called, has furnished, ever since the date of its publication, the nomenclature of all the fainter stars employed in the daily operations of astronomy; it has furnished the working catalogues which are essential for the more exact determination of the places of all these stars; it has given us the first accurate data for determining the distribution of the stars according to magnitude and apparent position in the heavens, and is the first solid existing basis for founding any theory as to the constitution of the stellar universe. To complete the 'Durchmusterung' for the remaining portion of the heavens was therefore the most pressing need of modern astronomy. I commenced the work in 1885 by the aid of photography. I hope in two or three years, if I have the honour of lecturing again in this theatre, I shall then be able to tell you that the work in question is finished.

I should here explain that mere pictures of the stars are of comparatively little value, or rather of about the same value to an astronomer as a series of charts of parts of the world would be to a sailor if there were no lines of latitude or longitude marked upon them.

The every-day useful part of the 'Durchmusterung' is the catalogue giving the positions and magnitude of all the stars. That work is rapidly advancing in the hands of my able and enthusiastic friend, Professor Kapteyn of Groningen, who, with the aid of three assistants, has undertaken to devote five or six years of his life to the measurement of the Cape photographs and the computation of the results.

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When this has been finished, as I venture to think it also will be within five years, astronomers will be in possession of that preliminary survey of the whole heavens which is necessary for the more refined and elaborate researches which must follow as results of the Paris Congress.

[To be continued.]

CORRESPONDENCE.

To the Editors of 'The Observatory.'

The Colour of Achernar.

GENTLEMEN,—

The recent interesting discussion in the 'Observatory,' of the supposed change in the colour of *Sirius*, may perhaps excuse the following account of a rather remarkable instance of difference in the determinations of the colour of a bright star by different observers.

I was considerably surprised a day or two ago to find the bright, first-magnitude star *α Eridani* included in Mr. Chambers's "Working Catalogue of Red Stars," published in the April number of the 'Monthly Notices,' as being "red," because my own impressions of the colour of this star had been entirely different. It is also No. 28 of Birmingham's Catalogue of Red Stars, and in the notes to this Catalogue is described as "roth," on the authority of Engelmann, and with the reference to A. N. 1828. In 1886 *Achernar* was examined by me for colour on two occasions, with the following results:—On Feb. 9th of that year, with a $2\frac{3}{4}$-in. refractor, the star, when rather low down, was called "flushed white;" and on Feb. 28, with an opera-glass, it was described as "silvery white." In the 'Uranometria Argentina,' Gould remarks that "*Achernar* is at present a white star without apparent tinge of any sort." These later observations are all so entirely different from Engelmann's description of "roth," that any additional estimations of the colour of the star would be of much value, especially if made at about the same period as his observation. Are there any such in existence? It would obviously be of importance to know also under what conditions, instrumental and atmospherical, Engelmann's observation was made. I have not immediate access to the no. of the A. N. in which it appeared. Perhaps some one better favoured will kindly give the necessary information.

Yours faithfully,

West Brighton,
1887, May 23.

A. STANLEY WILLIAMS.

P.S.—The following errata in the 'Observatory' for April had escaped my notice. In the table of transits on p. 193, Mar. 29, $15^h\ 25^m$ should be $13^h\ 25^m$; April 21 should be April 20.

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The usual variable-star observations had been forwarded to Harvard College, and are now in print. Two long-period variables had been discovered, and a new star of the 7th magnitude in Cygnus, which has now faded to below the 10th magnitude.

It was resolved that the reports of the Council and Special Observer should be printed in the 'Journal' of the Society.

A somewhat desultory conversation ensued on the question of the abolition of the post of Special Observer and the adoption of a common seal for the Society; and in the end both questions were deferred for the further consideration of the Council.

Thanks were voted to the Auditors, contributors to the Journal, Directors of Sections, the President, the Scrutineers of the Ballot, and to the Council of the Royal Astronomical Society for the use of their rooms.

The following members and honorary associates of the Society were declared elected as Officers and Council for the coming year:—*President*, Mr. Denning; *Vice-Presidents*, Mr. Elger, Rev. T. E. Espin, Mr. Gore, and Mr. Newall; *Special Observer*, Mr. Gill; *Editor*, Mr. Sadler; *Librarian*, Mr. Defieux; *Secretary* and *Treasurer*, Mr. W. H. Davies; *Council*, Miss E. Brown, Majors Markwick and Watson, Messrs. Backhouse, Calver, Deane, Gill, Higgs, Lynn, Monck, Oliphant, and Tarrant. As representatives for the Pernambuco Branch, Messrs. Elger and Franks. *Directors of Sections*—Solar, Miss Brown; Lunar, Mr. Elger; Meteoric and Comet-seeking, Mr. Denning; Coloured Star, Mr. Franks; Double Star, Mr. Tarrant; Variable Star, Mr. Gore; Educational, Mr. Gill; Planetary (Jupiter), Mr. Denning.

Mr. Wassell read a paper, illustrated by diagrams, on "Methods of working and testing Specula."

The Meeting adjourned at 5.30 P.M.

The Applications of Photography in Astronomy.

[Continued from p. 272.]

BUT to return to the work that was meanwhile being done in Paris by the brothers Paul and Prosper Henry.

These astronomers had been engaged since 1871 in the construction of charts of the Ecliptic by the older processes of observation, but when they reached that portion of the heavens where the Milky Way crosses the Ecliptic, the number of stars became so overwhelming that the task of charting seemed almost too great for human patience and skill. But fortunately the time had come when dry-plate photography could be called in to aid, and this aid was in the hands of men singularly competent to develop such an opportunity to the fullest extent. The brothers Henry had long aspired to be not only distinguished practical astronomers, but, following the traditions of Huyghens and the Herschels, they

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desired also to be the artists of their own optical means. Bound together by strong brotherly affection and common tastes, gifted alike with practical talents of a high order, and with an energy and determination of character that permit no obstacle to success, these men thus happily united have devoted the spare hours of their busy astronomical duties at the Paris Observatory, first to the study of optics, and afterwards to the grinding and polishing of lenses and specula, which have won for them a now world-wide reputation as opticians of the highest rank.

I had the pleasure, a few weeks ago, of visiting the modest workshop attached to their house at Montrouge, and I shall not soon forget that visit, nor the many lessons moral as well as practical which I learned.

Every detail of their process of working has been evolved by themselves; they employ no assistant, and their every appliance is simple and practical in a degree which I can only compare with the simple and practical character of the men who designed it.

Such were the men above all others to develop the application of photography to the charting of the heavens. They had high appreciation of the value of the work which they were about to undertake, they had the fullest knowledge of the requirements of the case, and they had the practical skill which enabled them to perfect the necessary apparatus. Their first attempts were made with a telescope of six inches aperture (the object-glass being specially ground for photographic work), and the tube was temporarily adapted to an existing equatorial stand.

With an exposure of forty-five minutes, pictures of stars were obtained to the 12th magnitude, in which the star disks were quite round and sharply defined.

Fully appreciating the beauty of this result, and seeing its importance, Admiral Mouchez boldly faced many administrative difficulties, and accepted without delay the proposals of the brothers Henry to construct an object-glass of thirteen inches aperture and about 11 feet focal length, as well as the offer of M. Gautier to mount the same on a suitable stand. The new instrument was mounted in May 1885. A photograph of the complete instrument is now on the screen.

Both from an optical as well as a mechanical point of view, the new instrument was admirably adapted for its intended work, and the results obtained by the brothers Henry, and rapidly published and circulated by Admiral Mouchez, at once astonished and delighted the astronomical world.

I now show a few of the more remarkable of these star pictures on the screen.

After such results as these there was no longer room for doubt or delay. The exquisite precision of these pictures, the sharpness and roundness of the images of the stars, and the results of actual measurement on the plates, proved that all necessary accuracy had been attained.

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The means of rapidly obtaining the data for an accurate survey of the heavens on a very large scale were now within the reach of astronomers, and the time for decisive action had arrived.

The work, however, was too extensive to be undertaken at a single observatory, or even by a single country, and it was agreed on all hands that international co-operation was essential for its execution in a sufficiently short space of time.

I need not enter into the details of preliminary consultation or correspondence, but at last a time was fixed, and invitations were issued by Admiral Mouchez, Director of the Paris Observatory, under the auspices of the Paris Academy of Sciences, for an International Congress of Astronomers to be held at Paris.

A preliminary committee having arranged the general order of business, the Congress was opened on the 16th April, and its thoroughly representative character will be understood from the following statement of the nationalities of the members present:—

France	20	U.S America..	3	Spain	1
England and Colonies....	8	Austria	2	Switzerland ..	1
Germany	6	Sweden	2	Portugal	1
Russia	3	Denmark	2	Brazil.....	1
Holland.....	3	Belgium.....	1	Argentine Republic.....	1
		Italy	1		

Before the Conference, a great many people, I will not say astronomers, held that the chief object was to photograph as many stars as possible, and simply preserve these plates or issue photographic copies of them, so that astronomers of the future, by merely comparing one of these originals or copies with a similar photograph of the same part of the sky taken 50 or 100 years hence, would find out what stars had changed in position or magnitude, or whether any new star had appeared.

There is no doubt this was the view of the popular writers—it is very easily understood, and it appeals very directly to the imagination. Such a project alone would no doubt have had great importance, and would probably in the future have brought to light a great many very interesting isolated facts.

But for the broader and more refined purposes of astronomy, for the discussion of such great questions as the motion of the solar system in space, the common movement of large groups of stars, the accurate determination of precession, and the general refinement of astronomy of precision, these mere pictures would have no value.

It was essential for these larger and more permanently important ends that all data should be provided for the most refined determination of the *absolute* position of any star upon any plate. This view was endorsed by the Congress.

The objects of the survey of the heavens to be carried out were defined ultimately thus :—"To make a photographic chart of the

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sky for the present epoch, and to obtain the data for determining the positions and magnitudes of all the stars to the 14th magnitude," as that magnitude is at present defined in France.

At present there are no exact determinations of stellar magnitude to that order of faintness, and the considerations which really guided the Conference were, that stars which are called 14th magnitude are photographed by the Henrys with an exposure of about 15 minutes of time. With such an exposure the time required for the work contemplated by the Congress would not be too great, but to demand long exposures would lead to the loss of many plates by interruptions from clouds, &c., and would unduly prolong the time required for completion of the whole work. As it is, the number of stars photographed to 14th magnitude will number about 20 millions.

It was seriously urged that stars to the 15th or even 16th magnitude and higher should be photographed, but it was felt that there was real danger of failure in an attempt to do too much.

It no doubt produces a strong effect on the imagination to be told that astronomers are to be engaged on making charts of the sky which will contain 60 or 100 millions of stars, or photographing stars on their plates which cannot be seen at all in the most powerful telescopes. There is thus a strong temptation to yield to this demand for sensation, to produce a few astonishing plates with the loss of much precious time, and to sacrifice the real progress of astronomy to the love of the marvellous. Besides, what are you to do with pictures of 100 millions of stars when you have got them? What would be the use of pictures of all these stars, unless at some future time a sufficient number of astronomers were to arise to compare similar photographs, taken, say, one hundred years hence, with the photographs taken in our day? I am happy to think that the number of men who devote themselves to the pursuit of astronomy is on the increase; but I have no desire that the number of men in Great Britain who occupy themselves exclusively with astronomy will ever correspond with that in the floating island of Laputa, as described by Dean Swift, where all the men were exclusively occupied with astronomy, and had to be flapped on the head with little bladders containing parched peas to arouse them from their abstract occupations. And yet, unless something of this sort happens, I see no adequate prospect of the utilization of pictures of 100 millions of stars.

The Congress, therefore, very wisely limited their chart plates to the 14th magnitude. But, as was well said by M. Bouquet de la Grye, it was not necessary to summon fifty or sixty astronomers to a Congress to arrange for taking mere photographs of stars—a number of photographers provided with instruments like the Henrys could have done all that without a congress. It was very strongly felt that the true *raison d'être* of the Conference was to secure astronomical data precise and exact, as the operations of astronomers should be.

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Accordingly they resolved that:—

"In addition to the duplicate series of plates giving all the stars to the 14th magnitude, there should be a series of plates of shorter exposure to insure a greater accuracy in the micrometric measurement of the standard stars, and to render the construction of a catalogue possible. The plates intended for the formation of the catalogue shall contain all the stars to the 11th magnitude inclusive." That is to say, it was determined to catalogue the absolute places of stars to the 11th magnitude.

But no photographic plate of itself gives us any information about the absolute places of stars, though it gives the means to determine the relative positions of the stars on the limited area of each plate; you must trust to the old-fashioned meridian observations to determine the absolute places of the brighter stars on each plate, and then measure the position of the fainter stars relative to these standard stars.

Now if a plate is exposed long enough to get satisfactory pictures of stars to the 14th magnitude, the images of the standard stars of the 7th, 8th, and 9th magnitude will not have the highest perfection, and consequently the places of the fainter stars cannot be measured relative to the ill-defined standard stars with the highest precision.

This will be evident if we examine actual photographs.

One illustrates a short exposure (1 minute), the other a long exposure (30 minutes). The short exposure gives sharp definition of the brighter stars, the long exposure brings into view a much greater number of stars, but the sharp definition of the brighter stars is completely lost. Therefore if we wish to have determinations of *absolute* positions, we cannot have long exposures.

The meaning of the series of plates of short exposure, and showing stars only to the 11th magnitude, is thus explained:

Of stars to 11th magnitude there are about $1\frac{1}{2}$ millions in the sky, and a catalogue containing all these stars may be considered complete for the practical purposes of astronomy, because that magnitude is the faintest which can be measured with accuracy in the larger class of equatorials usually employed in working observatories.

I need not enter into detail about the technical means which are to be taken for eliminating the various sources of error, such as contraction of the photographic film in course of development, and so forth. All these points have been considered by the Congress, or put into the hands of specialists when it appeared that any particular point required further special study, and they are too technical to be entered upon here. The chart of stars to the 14th magnitude will be of importance for many purposes, such as the search for minor planets, and the trans-Neptunian planet, for variable stars, and for data as to the law of distribution of stars of the higher order of magnitude. But I do not hesitate to say that the work which astronomers of future generations will be most

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grateful for, and which will most powerfully conduce to the progress of astronomy, will *not* be the chart but the catalogue.

And now, Ladies and Gentlemen, I have dragged you through what I fear has so far been a weary account, to bring you to an apparently very uninteresting conclusion.

Catalogues and figures are not matters of much popular interest, and yet from such uninviting material has been built up the fair structure of the exact astronomy of the present day; and out of such materials have been evolved the facts which appeal so strongly to the minds of men, and most strongly so because men know that the conclusions rest not on mere imaginings alone, but on solid facts and figures also.

But now as to the practical execution of this useful work. After all the preliminary details of the operations have been fully discussed—when the instruments have been designed and made, and the mode of working and the methods of measurement and reduction have been devised, the practical execution of the work becomes one long round of routine labour, requiring skilled and careful superintendence it is true, but still routine work of a very trying character.

Such work never has been, and never will be, the occupation of the amateur or single-handed astronomer. Essential as such work is to the progress of astronomy, it can only be executed at regular Government establishments, and therefore the conclusions of the Conference will have to be submitted to the various Governments, and the necessary votes of money must be secured. France has already definitely sanctioned the funds for four photographic telescopes of the kind which the Conference has decided to adopt for the work. And we cannot doubt that the modest claims which will be made on England's treasury for her share in this great work will be liberally responded to.

But there are other applications of photography to astronomy which have a daily growing importance. It was desirable that the Conference should recognize this work, and establish relations with those engaged upon it.

Accordingly the following resolution was passed:—

"The Congress expresses the desirability of there being a special committee which shall occupy itself with the applications of photography to astronomy, other than the construction of the chart. It recognizes the importance of these applications and the relations which it is desirable to establish between different kinds of work. The Congress request Messrs. Common and Janssen to undertake the realization of this proposition."

At first sight this may appear a somewhat barren resolution—but indeed it is not so. It must be remembered that the Congress was convened for the purpose of discussing a special object; it had arrived at definite conclusions and recommendations in connection with that object, and it was felt that to go beyond that object might imperil the adoption of its recommendations by the various Governments.

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But in the hands of men like Common and Janssen the resolution of the Conference is not likely to be a barren one, indeed it is certain that it will not be so, for they are already taking steps to unite fellow-workers in this field.

Their Committee will associate itself with those who are engaged upon the Charts, and will follow up in detail and with special instruments and methods the subjects of interest which from time to time will be encountered by the routine workers.

So remarkable has been the progress of the miscellaneous application of photography to astronomy within the past year, that some account of it is essential to bring the history of the subject up to date.

For example we have the recent work of Professor Pritchard, of Oxford.

He has applied photography during the past year to the most refined and difficult problem of practical astronomy, viz. the determination of the annual parallax (*i. e.* the distance) of the fixed stars. He has selected for experiment the interesting double star 61 Cygni. One of the original negatives of the series is now on the screen. This star, as is well known, was selected by Bessel, on account of its large proper motion, as the most suitable star for his first experiment. It was probable, because its large apparent motion among the stars was so great, its real distance from us would be less than that of stars of less apparent motion. Bessel's observations with the Königsberg heliometer proved this to be the case, and his discussion of these observations first convinced astronomers that the measurement of interstellar spaces was a problem not entirely beyond their reach.

Prof. Pritchard has now photographed the star during a whole year, and within a few days he promises that we shall have the results of his measurements of the plates. It will be of great interest to compare his results with previous independent determinations of the parallax of the same star made by other astronomers with different means; but it will be still more interesting for the future of astronomy to compare the amount of accuracy which the photographic method affords, as compared with the older existing methods. From preliminary results published by Prof. Pritchard we are led to expect a very high accuracy from the new process.

So far, however, as present experience goes, we shall not be able to apply this new method to the measurement of the parallax of very bright stars, because, when the plates have been exposed long enough to obtain pictures of the faint comparison stars, the disks of the brighter stars become too large and ill-defined for exact measurement. It may be that this obstacle will yet be overcome, but at present it has still to be faced.

On the question of the comparative merits of refractors and reflectors as the proper instruments for photographic use, very elaborate comparison has been instituted, and much discussion has been held.

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From the simple facts, that the best work yet done has been done in stellar photography by refractors, and that they are in many ways more convenient and simple in use than reflecting telescopes, the Paris Congress unanimously adopted the refractor as the instrument to be adopted for the international star charts.

But here is a very remarkable picture taken with the Oxford reflector, which shows star-disks very sharp and very round over a very large field of view, viz. eighty minutes of radius.

In the photography of special objects, such as star-clusters and nebulæ, much has been done.

Common's exquisite photograph of the great nebula of Orion you have seen before in this theatre, and for exquisite beauty of detail it has never been surpassed. But of this we may be sure that, if Mr. Common is spared in health and strength to complete the great reflector of five feet aperture upon which he is now engaged, that photograph, beautiful as it is, will be far surpassed.

Here is a photograph of the same object by Mr. Roberts. So short is the proportional focus of his telescope, so sensitive the plates he has employed, that the detail of the brighter parts has been completely burnt out; but we have faint outlying detail which is not at all shown in Mr. Common's photographs.

Here is another photograph of the same object by Professor Pickering, taken with a four-lens objective, of eight inches aperture and very short focus, and including a field of 5 degrees square. Exposure 82 min. This shows what can be done with such a combination.

In 1885 the brothers Henry, photographing the Pleiades on November 16th, discovered a new nebula, near the bright star Maia in the group. Here on the screen is a copy of the original negative by which the discovery was made. You observe the nebula like a filmy projection from one of the stars.

After the nebula had been discovered by photography it was found to be visible in the great telescope of 30 inches aperture at Pulkowa. But to *discover* is one thing, to see after discovery is another.

Strangely enough this new nebula was really photographed, a fortnight before its discovery at Paris, by Professor Pickering at Cambridge in America. In exhibiting the photograph to the National Academy of Sciences five days before Henry's discovery, Professor Pickering pointed out the "wing" attached to the star; but there was only one plate shown, and the impression was that the mark was due to a defect in the gelatine film.

Here, however, is another picture of the Pleiades taken at Cambridge with the same instrument and an exposure of eighty-two minutes, which shows nebulosity about more than one star of the group.

And here is a copy of a negative by Mr. Roberts, of Liverpool, with an exposure of three hours. The star-disks are of course

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large and ill-defined; but the quantity of nebula, invisible to the eye in the largest telescopes, is quite surprising.

These photographs appear to prove conclusively that the nebula and the stars in this group are one system; the doctrine of chances renders it almost an impossibility to suppose that such a symmetrical arrangement of nebulous matter with respect to the stars could exist by chance, if the stars were projected in front of a far distant background of nebulous matter.

Here is a photograph of the stars surrounding the celebrated variable star η Argus, taken at the Cape with the telescope of 9 inches aperture, generously presented to me for such work by Mr. James Nasmyth. The nebula surrounding this star is very faint compared with the Orion nebula, and it seems to be deficient in actinic rays, and, besides, the telescope is intended for stellar photography by its long focal length, and not for nebulæ, which require a shorter proportional focus—*i. e.* more intrinsically brilliant image.

Still there is the nebula, and I believe this is the only existing photograph of the object. The exposure was $2\frac{3}{4}$ hours, and yet although the original negative has been enlarged four diameters the star-disks remain well defined. The corresponding region of the sky is less than the Moon's apparent diameter, and of the many thousands of stars visible on the photograph not a single one is visible to the naked eye. The star η Argus was in 1843 nearly the brightest star in the heavens, in fact second only to Sirius; it is now between the 7th and 8th magnitude.

Here is a star-cluster in Argus. The star-disks are not so sharply defined, but the original negative has been much magnified to bring out the star-disks.

Here is a photograph, also taken at the Cape, of the wonderful star-cluster ω Centauri. It is the finest globular cluster in the heavens, and I do not know that I have ever seen the separation of the central stars so distinct with the eye as they are in this photograph. Perhaps by photographing we shall learn what motions occur in each cluster. This negative has been enlarged four diameters from the original.

Here is a photograph of the well-known cluster in Hercules, taken by Mr. Roberts of Liverpool, and a still more wonderful one by the Henrys of Paris. They must be magnified more highly to give any idea of their quality.

When the objects are bright, such as bright double stars, or planets, or the Moon, we can enlarge the image produced by the telescope, by aid of a secondary magnifier.

Because of the greater size of the original pictures thus produced, the granulation of the photographic film interferes to a less extent with the detail of the picture. Of course, this advantage is purchased at the cost of a longer exposure, because the same amount of light is spread over a larger area of the sensitive plate, and consequently the same area of the film receives less intense light.

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With very bright objects, such as the Sun, Moon, and planets, this is of little consequence, and may be an advantage, as permitting more accurate regulation of the exposure.

Here is a picture of the Sun photographed by M. Janssen at Meudon, near Paris. The exposure is less than 1-1000th of a second of time. And here is an enlarged photograph of the same spot, showing an amount of detail which no artist could convey by hand and eye, nor could he emulate the absolute accuracy of the photograph.

Here are some photographs of the planet Jupiter, taken at Paris, the original image being magnified 18 times.

Here is another showing the remarkable red spot—you even have before your eyes evidence of the rotation of Jupiter on its axis by the change in the position of the spot during the same evening.

This spot appeared in 1878 and measured about 30,000 miles in length by 7000 miles in breadth. It became of a deep red colour in 1879, and for the three following years was a most striking feature in the planet. It almost faded entirely in 1883, but has again become nearly as bright as it was in 1882.

Miss Clerke tells the story most admirably and suggestively in the last edition of her 'History of Astronomy,' to which work I would refer those of my hearers in whom these beautiful photographs may excite a sufficient interest.

To enter fully into the matter would demand a lecture to itself—and the minute-hand of that inexorable clock warns me that I must move on.

Here are some photographs of Saturn.

Here are some photographs of double stars. One of them, γ Virginis, taken at Greenwich, is the best photograph of a double star that I know.

Last of all I come to the most recent revelations of the power of photography as an aid to astronomy. Dr. Henry Draper, in 1872, was the first to photograph the lines in the spectrum of a star, but his admirable investigations were interrupted by death in 1882. In 1886, his widow placed in the hands of Professor Pickering, of Harvard College Observatory, in America, not only an ample sum of money for the purchase of costly apparatus, but also made a liberal provision for carrying on the work of photographic spectroscopy as a memorial to her husband. So noble a gift, and the execution of so pious a purpose, could not have been placed in abler or more active hands.

Within the past few weeks we have received the first-fruits of the Henry Draper Memorial Fund.

When I began preparation of this lecture, I cabled to Professor Pickering a request for some glass copies of his original negative. He kindly complied, and they arrived this morning. Time only permits me to show them rapidly, but those who remember Dr. Huggins's lectures on stellar spectra in this theatre, will recognize the enormous importance of such pictures as these.

The ingenuity of the adopted methods, the extraordinary success

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attained, the promise of rich harvest, exceeding our highest previous expectations, which the results afford, are themes upon which one could dilate for hours.

Here we have the spectra of the distant stars whose actual disks we can never hope to see, registering in these rhythmical lines the story of their constitution and temperature, with an accuracy and precision which not many years ago we should have been glad to obtain in the records of the spectrum of our own Sun.

And this is not all; not only have we such results for a few stars, but we are promised "that the complete work will include a catalogue of the spectra of all the stars of the 6th magnitude and brighter, a more extensive catalogue of spectra of stars brighter than the 8th magnitude, and a detailed study of the spectra of the bright stars." These are Prof. Pickering's own words.

What Prof. Pickering promises, we know, from long experience, that he will perform. We may also well say with him, that "a field of work and promise is open, and there seems to be an opportunity to erect to the name of Dr. Henry Draper a memorial such as heretofore no astronomer has received."

There is in England wealth enough and to spare. Many a rich man dies puzzled how to dispose of his money; and there is many a living man who would gladly give for such an object if he knew how to do so. There is field enough in astronomy, and there are men enough in England to do the work. Let us hope they will receive aid such as Prof. Pickering has received; and having done so, they will give an equally good account of their stewardship.

The miscellaneous applications of photography to astronomy offer a field so full of promise, so certain of immediate reward to those who are possessed of the necessary originality and the means to carry out their ideas, that there is more hope of private enterprise in that direction than in the more routine work of star-charting.

But tempting as these fields are, brilliant and interesting as are the discoveries to be found in them, there is in the work instituted by the Paris Congress an element that cannot be overlooked and which compels attention—it is this, the question of lapse of time. Every year that passes after that work has been carried out, increases its value and importance; every year that we neglect in doing it will be a reproach to the astronomers of the day. Into all the great problems which that work is destined to solve, the element of time enters—and time lost now in such work can never be recalled.

Of the Congress itself I would say a few last words. Its proceedings were characterized by an earnest spirit of work and entire absence of international jealousy. Our reception by the French was cordial and hospitable in the highest degree, the decisions of the Congress were almost unanimous, and were marked by a moderation and judgment which must render them acceptable to the responsible authorities of the various Governments.

Lastly, I would add that the good will which pervaded the meetings, the general success of the Congress as a whole, were in

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a great degree due to the general influence of the single-hearted, earnest-minded man who convened it—Admiral Mouchez.

D. GILL.

Observations of Comet 1886 e (*Finlay*).

(Made at Sydney Observatory, 1886, with the 11½-inch equatoreal and filar micrometer.)

1886, Sydney M.T.	Star.	No. Comps.	Comet—Star.		Comet's apparent		Observer.
			$\Delta\alpha$.	$\Delta\delta$.	α.	δ.	
d h m s			m s	′ ″	h m s	° ′ ″	
Oct. 26 8 56 20	1	15	+ 1 54·31	+36 37·95	18 32 4·67	−26 21 47·06	R.
Oct. 27 8 18 56	2	7	−12 30·67	− 7 57·32	18 35 42·79	−26 18 6·92	R.
Oct. 28 7 36 11	3	4	− 8 50·32	−11 58·00	18 39 23·13	−26 14 6·25	P.
Oct. 29 8 47 54	4	4	− 4 47·73	−16 37·92	18 43 25·70	−26 9 26·32	P.
Nov. 3 9 14 26	5	5	− 5 12·09	+12 41·67	19 3 22·54	−25 39 38·56	P.
Nov. 9 8 46 13	6	10	− 0 30·95	−11 14·98	19 28 37·05	−24 46 39·72	P.
Nov. 26 8 56 13	7	5	−10 8·58	− 5 25·71	20 47 48·21	−20 12 39·36	P.
Nov. 30 8 50 24	8	7	− 3 52·30	+11 0·60	21 7 43·07	−18 38 29·48	P.
Dec. 9 8 38 36	9	6	− 6 45·35	− 0 3·23	21 53 33·29	−14 25 1·45	P.

Adopted Mean Places for 1886·0 of Comparison Stars.

Star.	α.	Red. to app. place.	δ.	Red. to app. place.	Authorities.
	h m s	s	° ′ ″	″	
1	18 30 8·67	+1·69	−25 45 17·59	+ 8·48	Stone, 10131; Sydney trans.-circle, 10/4/87.
2	18 48 11·71	+1·75	−26 26 13·11	+ 8·87	Melb. 960; Cordoba Gen. Cat. 25874; Stone, 10284.
3	18 48 11·71	+1·74	−26 26 13·11	+ 8·86	Melb. 960; Cordoba Gen. Cat. 25874; Stone, 10284.
4	18 48 11·71	+1·72	−26 26 13·11	+ 8·87	Melb. 960; Cordoba Gen. Cat. 25874; Stone, 10284.
5	19 8 32·92	+1·71	−25 27 6·70	+ 9·81	2nd Radcliffe Cat. 1835; Yarnall 8193; Stone, 10446.
6	19 29 6·29	+1·71	−24 58 5·19	+10·49	Greenwich new 7-year Cat. 2151; Stone, 10580.
7	20 57 54·99	+1·80	−20 18 18·15	+13·08	2nd Rad. Cat. 2050; Greenw. 9-year Cat. 1969; Stone, 11187.
8	21 11 33·57	+1·80	−18 27 42·51	+13·63	Cape Cat. 1850, 4251; Greenw. new 7-year, 2411.
9	22 0 16·74	+1·90	−14 25 19·81	+15·13	Greenwich new 7-year Cat. 2521; Stone, 11609.

Observations corrected for Refraction, but not Parallax. Comet faint and small; no nucleus seen. Observers: R.=Russell; P.=Pollock.

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